

PATENT ABSTRACTS OF JAPAN

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(54) COMPLEX BAND-PASS FILTER

(57)Abstract:

PROBLEM TO BE SOLVED: To improve the distortion of a signal in a filter passing band due to frequency characteristics of an operational transconductance amplifier.

SOLUTION: A complex band-pass filter which has 1st to 6th OTA21 to OTA26 and 1st and 2nd capacitors 27 and 28 is provided with a 1st resistance 29 (or transistor) which has a resistance value R_a for canceling the distortion of an in-phase component signal in the passing band between the 1st capacitor 27 on the output side of the first OTA21 and the earth and with a 2nd resistance 30 which has a resistance value R_b for canceling the distortion of an orthogonal component signal in the passing band between the 2nd capacitor 28 on the output side of the second OTA22 and the ground. Those resistance values R_a and R_b are set with $2/(\omega bC)$. Consequently the signals in the passing band have no distortion.

CLAIMS

[Claim(s)]

[Claim 1] The 1st transconductance element which inputs an in-phase component signal of quadrature modulation and defines an output gain of this in-phase component signal.

The 1st capacitor for being connected between an output terminal of this 1st transconductance element and a ground and defining pass band width of an in-phase component signal.

An in-phase component output side element which inputs an output of the above-mentioned 1st transconductance element and defines pass band width of an in-phase component signal with combination with the 1st capacitor of the above. The 2nd transconductance element which receives a quadrature component signal of quadrature modulation and defines an output gain of this quadrature component

signalThe 2nd capacitor for being connected between an output terminal of this 2nd transconductance elementand a groundand defining pass band width of a quadrature component signalA quadrature component output side element which inputs an output of the above-mentioned 2nd transconductance elementand defines pass band width of a quadrature component signal with combination with the 2nd capacitor of the aboveAn element for frequency shifts for being connected between a node of the above-mentioned 1st transconductance element and an in-phase component output side elementthe above-mentioned 2nd transconductance elementand a node of a quadrature component output sideand shifting center frequency of a pass band.

Are the complex band pass filter provided with the aboveand it is connected between an output terminal of the above-mentioned 1st transconductance elementand a groundThe 1st resistance generating element which generates resistance for negating distortion of a pass band of an in-phase component signal generated with the limited frequency characteristic of this 1st transconductance element and the above-mentioned element for frequency shiftsIt is connected between an output terminal of the above-mentioned 2nd transconductance elementand a groundThe 2nd resistance generating element which generates resistance for negating distortion of a pass band of a quadrature component signal generated with the limited frequency characteristic of this 2nd transconductance element and the above-mentioned element for frequency shifts was provided.

[Claim 2]A complex band pass filter given in above-mentioned claim 1 characterized by using a resistance element as the above 1st and 2nd resistance generating element.

[Claim 3]A complex band pass filter given in above-mentioned claim 1 using a transistor element which operates in a triode field as the above 1st and 2nd resistance generating element.

[Claim 4]The limited frequency characteristic of the above-mentioned 1st transconductance element and an element for frequency shifts and a value of the 1st capacitor of the above determine resistance of the above-mentioned 1st resistance generating elementA complex band pass filter given in above-mentioned claims 1 thru/or 3 determining resistance of a resistance generating element of the above 2nd with the limited frequency characteristic of the above-mentioned 2nd transconductance element and an element for frequency shiftsand a value of the 2nd capacitor of the above.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]This invention relates to a complex band pass filter and the complex band pass filter for being used for a phase convertera Hilbert

transformation machine etc. 90 degrees and oppressing an image signal especially.
[0002]

[Description of the Prior Art] In recent years the Low-IF method which sets an intermediate frequency (IF) as several MHz or less attracts attention with the spread of walkie-talkie terminals instead of the superheterodyne system which is the conventional receiving method. If this Low-IF method is adopted the external IF filter with a big outside dimension which was needed with the above-mentioned superheterodyne system can be removed and one-chip-izing and the advantage that the price can fall will be acquired in a receive section.

[0003] However in this Low-IF method since received frequency (RF) and the frequency of a local oscillator are near oppression of an image signal becomes indispensable and a complex band pass filter exists as a means to oppress this image signal. There is a thing using operational research transconductance amplifier (referred to as OTA below) as a kind of this complex band pass filter and this For example IEICE TRANS. FUNDAMENTALS Vol. E80-A and No. 9 month September 1997 It is indicated to the paper of Xiaoxing ZHANG carried on 1724 pages from 1721 pages Implementation of Active Complex Filter with Variable Parameter Using OTA etc.

[0004] The composition of the primary complex band pass filter described in the above-mentioned paper is shown in drawing 4.

In this filter input signal X_R of the in-phase component of quadrature modulation is inputted The 1st OTA1 with the transconductance of $gm3a$ and the output side of this 1st OTA1 are connected 3rd OTA3 with the transconductance of $gm1a$ is provided and output signal Y_R of an in-phase component is outputted from this the 3rd OTA3.

On the other hand input signal X_I of the quadrature component of quadrature modulation is inputted and the 2nd OTA2 with the transconductance of $gm3b$ and the output side of this 2nd OTA2 are connected 4th OTA4 with the transconductance of $gm1b$ is provided and output signal Y_I of a quadrature component is outputted from this the 4th OTA4.

[0005] In order to achieve a frequency shift function between the nodes B of the above-mentioned 1st OTA1 the node A of 3rd OTA3 and the above-mentioned 2nd OTA2 and 4th OTA4 The 5th OTA5 and 6th OTA6 are provided this 5th OTA5 has a transconductance of $gm2a$ and 6th OTA6 has a transconductance of $gm2b$. Between the above-mentioned node A and a ground the 1st capacitor 7 of capacity C_a is connected and the 2nd capacitor 8 of the capacity C_b is connected between the above-mentioned node B and a ground.

[0006] And transfer function $H(s)$ [s of such primary complex band pass filter : complex variable] In the above-mentioned transconductance it is $gm1a=gm1b=gm1$ $gm2a=gm2b=gm2$ and $gm3a=gm3b=gm3$ and when it is considered as $C_a=C_b=C$ it is given by a following formula.

[0007]

[Equation 1]

j is an imaginary unit and is $j^2 = -1$.

[0008] According to such a complex band pass filter about input signal X_R of an in-phase component. A gain determined by transconductance $gm3a$ and output signal Y_R of the pass band width determined by capacity Ca and transconductance $gm1a$ is obtained. About input signal X_I of a quadrature component output signal Y_I of the pass band width which is a gain determined by transconductance $gm3b$ and is determined by the capacity Cb and transconductance $gm1b$ is obtained. And frequency is shifted to those for Masakata only the quantity determined with the above-mentioned capacity Ca and Cb and transconductance element $gm2a$ and $gm2b$.

[0009] The frequency characteristic which took angular-frequency ω along the horizontal axis is shown in drawing 5.

According to the above-mentioned complex band pass filter only ω_c can shift center frequency for example from $-\omega_0$ like the frequency characteristic 100 to the frequency characteristic 101 of the bandwidth of $+\omega_0$ and although it lets positive frequency pass by this the filter which does not let negative frequency pass is obtained.

And a high order complex band pass filter is formed by carrying out cascade connection of such a primary complex band pass filter.

[0010] The composition of the 4th Bata Wace type complex band pass filter is shown in drawing 6.

This shall be 2 MHz in center frequency and shall be 1 MHz in pass band width for example.

The 1st filter 10 of a graphic display Namely $gm1a = gm1b = 29 \mu S$ (siemens) It is set as $gm2a = gm2b = 137.7 \mu S$ $gm3a = gm3b = 59 \mu S$ and $aCa = Cb = 10 pF$ value and the 2nd following filter 11 It is set as $gm1a = gm1b = 29 \mu S$ $gm2a = gm2b = 113.6 \mu S$ $gm3a = gm3b = 59 \mu S$ and $aCa = Cb = 10 pF$ value and the 3rd filter 12 It is set as $gm1a = gm1b = 12 \mu S$ $gm2a = gm2b = 154.7 \mu S$ $gm3a = gm3b = 59 \mu S$ and $aCa = Cb = 10 pF$ value and the 4th filter 13 of a final stage It is set as $gm1a = gm1b = 12 \mu S$ $gm2a = gm2b = 96.6 \mu S$ $gm3a = gm3b = 59 \mu S$ and $aCa = Cb = 10 pF$ value.

[0011] The ideal frequency characteristic of the 4th Bata Wace type complex band pass filter of drawing 6 is shown in drawing 7.

2 MHz is made into center frequency and the characteristic of the bandwidth which lets positive frequency pass is obtained so that it may be illustrated.

[0012]

[Problem(s) to be Solved by the Invention] However the frequency characteristic of the complex band pass filter of above-mentioned drawing 7 It is when the frequency characteristic of the transconductance gm of each OTA (operational research transconductance amplifier) 1-6 is ideal and there was a problem that a big distortion arose into the pass band portion of a signal actually.

[0013] When the frequency characteristic of the actual complex band pass filter is

shown in drawing 8 and the frequency (cut off frequency) which falls by -3 dB by gm of this OTA is 20 MHz as it is shown in drawing 8A a big distortion occurs in the pass band width (1 MHz) centering on the frequency of 2 MHz.

[0014] This invention is made in view of the above-mentioned problem and the purpose is to provide the complex band pass filter which can improve distortion of the signal of the filter pass band region resulting from the frequency characteristic of operational research transconductance amplifier good.

[0015]

[Means for Solving the Problem] To achieve the above objects an invention concerning claim 1 The 1st transconductance element which inputs an in-phase component signal of quadrature modulation and defines an output gain of this in-phase component signal The 1st capacitor for being connected between an output terminal of this 1st transconductance element and a ground and defining pass band width of an in-phase component signal An in-phase component output side element which inputs an output of the above-mentioned 1st transconductance element and defines pass band width of an in-phase component signal with combination with the 1st capacitor of the above The 2nd transconductance element which receives a quadrature component signal of quadrature modulation and defines an output gain of this quadrature component signal The 2nd capacitor for being connected between an output terminal of this 2nd transconductance element and a ground and defining pass band width of a quadrature component signal A quadrature component output side element which inputs an output of the above-mentioned 2nd transconductance element and defines pass band width of a quadrature component signal with combination with the 2nd capacitor of the above An element for frequency shifts for being connected between a node of the above-mentioned 1st transconductance element and an in-phase component output side element the above-mentioned 2nd transconductance element and a node of a quadrature component output side and shifting center frequency of a pass band In a preparation ***** band pass filter it is connected between an output terminal of the above-mentioned 1st transconductance element and a ground The 1st resistance generating element which generates resistance for negating distortion of a pass band of an in-phase component signal generated with the limited frequency characteristic of this 1st transconductance element and the above-mentioned element for frequency shifts It is connected between an output terminal of the above-mentioned 2nd transconductance element and a ground The 2nd resistance generating element which generates resistance for negating distortion of a pass band of a quadrature component signal generated with the limited frequency characteristic of this 2nd transconductance element and the above-mentioned element for frequency shifts was provided.

[0016] An invention concerning claim 2 used a resistance element as the above 1st and 2nd resistance generating element. An invention concerning claim 3 used a transistor element which operates in a triode field as the above 1st and 2nd resistance generating element. An invention concerning claim 4 determines resistance of the above-mentioned 1st resistance generating element with the

limited frequency characteristic of the above-mentioned 1st transconductance element and an element for frequency shifts and a value of the 1st capacitor of the above. The limited frequency characteristic of the above-mentioned 2nd transconductance element and an element for frequency shifts and a value of the 2nd capacitor of the above determine resistance of a resistance generating element of the above 2nd.

[0017] According to the above-mentioned composition it becomes possible for example during the 1st capacitor and a ground to cancel distortion of a signal of a pass band by arranging a resistance element or a transistor element to each between the 2nd capacitor and a ground. And distortion of this signal can be certainly lost by making resistance given by the above-mentioned resistance element or a transistor element into a value shown in above-mentioned claim 4.

[0018] That is distortion of a pass band of an output signal generated with the limited frequency characteristic (characteristic of a cut off frequency) of a transconductance element and an element for frequency shifts (gyrator element) can be expressed with the transfer function $H(s)$ of the following expression 2.

[0019]

[Equation 2]

ω_0 is angular frequency.

[0020] With this expression 2 as for R above ω_0 serves as resistance of the 1st or 2nd resistance generating element with a frequency characteristic [that a transconductance element and the element for frequency shifts are limited (for example cut off frequency)]. It will newly generate very much (portion of s/ω_0) with the limited frequency characteristic of a transconductance element and the element for frequency shifts and that pole will bring distortion to a pass band so that the denominator of this expression 2 may show. Then the value of $R=2/(\omega_0 C)$ is inserted in R of a numerator so that this newly generated pole may be negated and it carries out as [disappear / by this / the excessive pole of a denominator]. However the transfer function $H(s)$ of this expression 2 is materialized when the frequency characteristic of a transconductance element and the element for frequency shifts is equal. The above-mentioned angular-frequency ω_0 is a value which becomes settled in both angular-frequency ω_0 of a transconductance element and angular-frequency ω_0 of the element for frequency shifts.

[0021]

[Embodiment of the Invention] The composition of the complex band pass filter concerning the 1st example of this invention is shown in drawing 1 and this filter. Like the case of drawing 4 have a transconductance of gm_3 and it has a transconductance of the 1OTA (operational research transconductance amplifier) 21 which inputs input signal X_R of the in-phase component of quadrature modulation and gm_1 . It has a transconductance of the 3OTA 23 which is arranged in the latter part of above-mentioned 1st OTA 21 and outputs output signal Y_R of an

in-phase component and $gm3b$ It has a transconductance of the 2OTA22 which inputs input signal X_i of the quadrature component of quadrature modulation and $gm1b$ and the 4th OTA24 which is arranged in the latter part of above-mentioned 2nd OTA22 and outputs output signal Y_i of a quadrature component is provided.

[0022] In order to achieve a frequency shift function between the nodes B of the above-mentioned 1st OTA21 the node A of 3rd OTA23 and the above-mentioned 2nd OTA22 and 4th OTA24 6th OTA26 (gyrator element) with the transconductance of the 5OTA25 and $gm2b$ with the transconductance of $gm2a$ is provided. Between the above-mentioned node A and a ground the 1st capacitor 27 of capacity C_a is connected and the 2nd capacitor 28 of the capacity C_b is connected between the above-mentioned node B and a ground.

[0023] And between the 1st capacitor 27 of the above and a ground the series connection of the 1st resistance 29 of resistance R_a is carried out and the series connection of the 2nd resistance 30 of the resistance R_b is carried out between the 2nd capacitor 28 of the above and a ground. This resistance R_a and R_b can be calculated as follows. The above-mentioned transconductance and capacity are made into $gm1a=gm1b=gm1gm2$ $a=gm2b=gm2gm3a=gm3b=gm3$ and $C_a=C_b=C$ If gm makes f_b frequency (cut off frequency) downed -3 dB and makes angular frequency $\omega_{a,b}=2\pi f_b$ above-mentioned R_a and the value of R_b will be calculated by $R_a=R_b=R=2/(\omega_{a,b}C)$.

[0024] The transconductance of 5th OTA25 and transconductance $gm2$ of 6th OTA26 the above-mentioned resistance R mainly The transconductance of 1st OTA21 and the frequency characteristic of transconductance $gm3$ of 2nd OTA22 determine If angular frequency $\omega_{a,b}2$ and the above gm of -3 dB fall [angular frequency] the angular frequency the above gm of -2 dB falls [angular frequency] is set to $\omega_{a,b}3$ It is preferred $R < R_{eq}$ and in the case of $\omega_{a,b}2 > \omega_{a,b}3$ to set up so that the relation of $R > R_{eq}$ may be materialized on the other hand in the case of $\omega_{a,b}2 < \omega_{a,b}3$ and they can ensure dissolution of distortion by this. Above R_{eq} is the resistance in $\omega_{a,b}2=\omega_{a,b}3=\omega_{a,b}$ and is $R_{eq}=2/(\omega_{a,b}C)$.

[0025] If signal X_R of an in-phase component is inputted into 1st OTA21 according to the complex band pass filter of the above example [1st] by the gain determined by transconductance $gm3a$. And if signal Y_R of the pass band width determined by capacity C_a and transconductance $gm1a$ is outputted from the 3OTA23 and input signal X_i of a quadrature component is inputted into 2nd OTA22 Signal Y_i of the pass band width which is a gain determined by transconductance $gm3b$ and is determined by the capacity C_b and transconductance $gm1b$ is outputted from the 4OTA24. As drawing 5 explained frequency is shifted to those for Masakata only the quantity determined with the above-mentioned capacity C_a and C_b and transconductance element $gm2a$ and $gm2b$.

[0026] The frequency characteristic of the 4th Bata Wace type complex band pass filter which carried out cascade connection of the filter of drawing 1 is shown in drawing 2. [when the frequency (cut off frequency) which makes the value of gm of OTA 21-26 and the capacity C of the capacitors 27 and 28 be the same as that

of the case of above-mentioned drawing 6 and falls by -3 dB by gm of above-mentioned OTA 21-26 in this example is 20 MHz]It could be $R_a = R_b = R = 2 / (\omega_p C) = 2 / (2\pi 20 \times 10^6 \text{ and } 10 \times 10^{-12}) = 1592 \text{ ohm}$. From this drawing 2 it is understood that distortion is lost into the pass band portion (1-MHz field centering on 2 MHz).

[0027]The composition of the complex band pass filter concerning the 2nd example of this invention is shown in drawing 3 and a transistor element is used for this 2nd example as a resistance generating element. In drawing 4 although the composition of the 1st thru/or 6th OTA 21-26 and the 1st and 2nd capacitors 27 and 28 is the same as that of the 1st example The series connection of the 1st transistor 31 that operates in a triode field between the 1st capacitor 27 of the above and a ground is carried out and the series connection of the 2nd same transistor 32 is carried out between the 2nd capacitor 28 of the above and a ground.

[0028]And with this 1st transistor 31 by changing the gate voltage V_a resistance R_a is generated and the resistance R_b is generated by changing the gate voltage V_b with the 2nd transistor 32. As this resistance R_a and R_b the value obtained by $2 / (\omega_p C)$ as mentioned above is set up. According to such 2nd example the resistance R_a and R_b can be changed with the 1st transistor 31 and the 2nd transistor 32 and distortion of the signal of a pass band can be canceled good like the case of the 1st example by this.

[0029]

[Effect of the Invention]In [according to / as explained above / this invention] a complex band pass filter The resistance element or transistor which generates the resistance for negating distortion of the pass band of an in-phase component signal between the output terminal of the 1st transconductance element and a ground is arranged Since the resistance element or transistor which generates the resistance for negating distortion of the pass band of a quadrature component signal between the output terminal of the 2nd transconductance element and a ground has been arranged It becomes possible to obtain a high order complex band pass filter with a good frequency characteristic without being able to improve distortion of the signal of the filter pass band region resulting from the frequency characteristic of operational research transconductance amplifier good and enlarging circuit structure.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1]It is a circuit diagram showing the composition of the complex band pass filter concerning the 1st example of this invention.

[Drawing 2]It is a figure showing the frequency characteristic of the 4th complex band pass filter of an example (only positive frequency is shown).

[Drawing 3]It is a circuit diagram showing the composition of the complex band

pass filter concerning the 2nd example.

[Drawing 4] It is a circuit diagram showing the composition of the conventional complex band pass filter.

[Drawing 5] It is an explanatory view showing the frequency shift in a complex band pass filter.

[Drawing 6] It is a figure showing the composition of the 4th Bata Wace type complex band pass filter which carried out cascade connection of the complex band pass filter.

[Drawing 7] It is a figure showing the ideal frequency characteristic in the complex band pass filter of drawing 6.

[Drawing 8] It is a figure showing distortion of the signal produced with the complex band pass filter of drawing 6 (only positive frequency is shown).

[Description of Notations]

121 -- The 1st OTA (operational research transconductance amplifier)

222 -- The 2nd OTA 323 -- The 3rd OTA

424 -- The 4th OTA 525 -- The 5th OTA

626 -- The 6th OTA

727 -- The 1st capacitor

828 -- The 2nd capacitor

29 -- The 1st resistance and 30 -- The 2nd resistance

31 -- The 1st transistor

32 -- The 2nd transistor.
